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# ARMORED MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

INDEXED

PROJECT NO. 6 - VISION IN TANKS

Third Partial Report

On

Sub-Project No. 6-2, Study of Characteristics and Limitations of  
Present Visual Devices in Tanks

Sub-Project No. 6-4, Study of Means of Improving Sighting Telescopes

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TELESCOPIC SIGHTS T-106-E1 and M-71-F IN COMPARISON  
WITH OTHER TANK SIGHTS

Project Nos. 6-2, 6-4

INFORMATION COPY

23 February 1944



ARMORED MEDICAL RESEARCH LABORATORY  
Fort Knox, Kentucky

Project No. 6-2, 6-4  
413.74-3

23 February 1944.

Report on

Telescopic Sights T-106-E1 and M-71-F in Comparison  
With Other Tank Sights

1. PROJECT: No. 6 - Vision in Tanks; Third Partial Report on Sub-Projects No. 6-2 - Study of Characteristics and Limitations of Present Visual Devices in Tanks; and 6-4 - Study of Means of Improving Sighting Telescopes.

a. Authority: Letter Commanding General, Headquarters Armored Force, Fort Knox, Kentucky, 400.112/6 GNOHD, dated September 24, 1942.

b. Purpose: To evaluate subject sights and to determine the useful scope of employment.

2. DISCUSSION:

a. Laboratory tests have been completed on the two new sights, together with identical tests on other sights now employed by the Armored Command. This permits a comparison as to improvement in design, needs for further improvement and suitability for type of employment.

b. Discussion of the advance in design that has been achieved, summary of tests on subject sights and other units, and comparison of scope of employment are given in the appendices.

3. CONCLUSIONS:

a. The three (3) power straight telescope type in large tube, T-106-E1, represents an outstanding improvement in design.

b. This three (3) power sight is suitable for low velocity weapons employing fixed or moving reticles which require a wide field of good definition.

c. The five (5) power sight, M-71-F, in identical mount, represents a substantial improvement; but fails to approach T-106 series in excellence of design.

d. This five (5) power sight is sufficiently improved over the previous model (T-92) to make interim employment for high velocity weapons practicable.



e. This sight (M-71-F) is limited to 4100 yards for use with the 90 mm gun, assuming the bore sight mark is placed twenty (20) mils above center of the field. Correspondingly less range will be obtained with the bore sight mark nearer the center. Used with the 75 mm gun, it will be satisfactory only to 2400 yards (again assuming bore sight mark is up twenty (20) mils).

#### 4. RECOMMENDATIONS:

a. T-106-El be employed with low velocity weapons, especially 105 mm Howitzer, where provision is made for mounting the large straight sight. A three (3) power sight of the periscopic offset type requiring less eye travel is desirable, however, and should be developed.

b. Sight T-106 be employed as a secondary fire control unit in conjunction with higher power sights for high velocity weapons.

c. The employment of M-71 series sight be restricted to high velocity weapons requiring higher power sight than now available and not necessitating a large field of good definition. (When periscope sight M-10 is available, there will be no need of combined employment in tanks for this sight (M-71) as it is not suitable as a secondary fire control unit.)

d. Series M-71 sights should be improved if they are to be employed in future vehicles.

(NOTE: The conclusions and recommendations set forth above have been concurred in by Headquarters, Armored Center, W. H. Nutter, Colonel, G.S.C., Chief of Staff.)

Submitted by:

Major F. S. Brackett, SnC

APPROVED: Willard Machle

WILLARD MACHLE

Colonel, Medical Corps  
Commanding

#### 7 Incls.

- #1 - Appendix I, Advance in Sight Design
- #2 - Appendix II, Performance Tests
- #3 - Table, General Properties of the Specific Design
- #4 - Appendix III, Employment of Sights
- #5 - Figure 1, Comparison of Resolving Power Fields at the Eye
- #6 - Figure 2, Comparison of the Appearance of Sight Fields
- #7 - Figure 3, Comparison of Sights by Quality of True Field



## APPENDIX I

### ADVANCE IN SIGHT DESIGN

1. One of these sights, the three (3) power T-106-El, demonstrates the practicability of the large field and large exit pupil sight of the straight tube type requested in January of the past year.
2. In the partial report by the Armored Medical Research Laboratory, "Visual Requirements, Characteristics and Limitations of Present Visual Devices in Tanks and Means for Improving Sighting Telescopes and Periscopes" Projects No. 6-1, 6-2, 6-4, File No. 413-74, of January 23, 1943, the desirability of increasing the exit pupil from 5.5 to 7 mm (or 7.5 if possible) was indicated as well as the need for larger field (62 to 75° apparent). It was emphasized at that time that at least two requirements would have to be met:
  - a. The diameter of the tube would have to be increased.
  - b. A highly corrected anastigmatic erector would have to be employed because of the large aperture, together with the moderate field, needed at this point in the optical train.
3. The first large telescopes submitted, T-93 - 3 power and T-92 - 5 power, met the first of these demands, but failed to provide the suitable highly corrected erector indicated. The result was telescopes which ostensibly had the properties of large exit pupil and field requested, but were completely inadequate in quality of performance.
4. The new sight designed by Eastman Kodak Company follows the line of development indicated and exhibits, as a result, excellent definition over wide field and provides a large exit pupil which is actually useful over its entire area.
5. Sight M-71-F (5 power), a substantial improvement over T-92, is intermediate in excellence between the T-92 and the high quality demonstrated in T-106.
6. For the sake of comparison of design, Figure 1 shows a plot of the resolving power at the eye for different angles in the apparent field. This makes it possible to appraise the merits of the different telescopes without regard to power.
  - a. Curves indicated for T-92 (5 power ) and T-93 (3 power) are so nearly identical to be within the range of individual sight variation. It will be noted that for sixty (60) seconds resolving power at the eye, sight T-106 has over six (6) times the field. Sixty (60) seconds resolving power at the eye is taken as a standard sight requirement. This represents the visual acuity attained by at least thirty (30) per cent of Armored Command gunners. A somewhat more lenient requirement of ninety (90) seconds at the



eye, representing approximately 20/20 vision by Snellen measurement, is equal to or less than the visual acuity of over eighty-five (85) per cent of Armored Command gunners. For this requirement, the T-106 provides over four (4) times the field.

b. The new sight M-71-F (5 power) is seen to lie intermediate between these two extremes. It increases the field over the T-92 by 50 to 75 per cent. It still, however, falls short of the critical field attained by the small M-70. It should be remembered, however, that the larger exit pupil of the M-71-F makes the problem substantially more difficult. However, if the more highly corrected type of erector used in the T-106 were employed, a similar result could be obtained in the five (5) power sight. In fact, from a very cursory examination of other pilot models, it is believed that superior designs have been developed which may approach the T-106 in performance.

7. In order to more readily compare the merits of the different sights now available to the Armored Command, their definitional properties are summarized in Figure 2 on the basis of the apparent radius of field for each value of resolving power.

a. Four gradations of resolution are indicated. The solid blocks of the histogram show the extent of standard resolving power adequate for the central vision of all but thirty (30) per cent of Armored Command gunners. The double hatched areas indicate the zones where ninety (90) seconds resolving power is attained, equal to or less than the ordinary visual attainments of more than eighty-five (85) per cent of the gunners. The single hatched area extends to the point where only 250 seconds of resolving power remain. This corresponds to the point approximately  $12^{\circ}$  off axis for a good eye. The open blocks extend to the limit of the remaining field. The definition here is sufficiently good to make the gunner aware of the existence of objects or to pick up motion and gun flashes.

b. While the critical vision of a good eye only extends a matter of  $1^{\circ}$  on either side of the fixation point, the eye is in continual scanning motion and requires standard definition wherever the attention of the gunner may necessarily be directed. Thus, if a telescope were designed to permit the eye to scan over a  $44^{\circ}$  field,  $22^{\circ}$  on either side of center, good definition should extend over some  $46^{\circ}$ . From this point, the definition may fall off in a manner similar to that of the eye without any apparent loss of sharpness. Thus, at the bottom of the diagram, the requirements of a good eye are indicated in a similar manner, together with a block in which the eye fixation point is displaced  $22^{\circ}$  to the right of center, so representing an arbitrary limit of excursion. Above the diagram for the eye is a diagram for a hypothetical telescope whose properties are designed to match the requirements of the eye in  $22^{\circ}$  excursion.

c. The common limits attained by different eyepieces are indicated at the top of the diagram. It will be seen that this hypothetical or ideal



telescope would have an ocular of the Erfle type similar to that employed in the four larger telescopes. The T-106 closely approximates this ideal telescope for  $22^{\circ}$  excursion. It has a greater range of sixty (60) second vision, but does not make adequate provision for the secondary vision of the eye out to  $12^{\circ}$  from center. The result would be that the use of the T-106 for an extreme excursion of say  $24^{\circ}$  to the right would give a slightly blurred effect in extreme right portions of the field. This is not a serious defect. The T-106 may be regarded as almost ideal for an excursion of  $16^{\circ}$  apparent, and reasonably satisfactory up to  $24^{\circ}$  apparent. Contrast this with the T-93 which would only give similar performance for an excursion of some  $3^{\circ}$ . The M-71-F provides for an excursion of over  $5^{\circ}$  while the small telescope M-70 is reasonably satisfactory for an excursion of 8 to  $9^{\circ}$ . Its chief limitation is that the lack of outer field robs the gunner of awareness of surrounding terrain and events. The periscopes M-4 and M-8 present so inadequate a field coverage as to use only a small fraction (seventeen (17) per cent) of the much needed vision possible to the gunner.

8. Samples of the M-10 or T-8 variations of the new dual periscope sight are not available at this time for comparative analysis. However, the problem of design for such a periscopic sight is much simpler and the possibilities of attainment far exceed those even of the T-106.



## APPENDIX II

### PERFORMANCE TESTS

1. Characteristics of the new sights are shown in Table 1, together with those of earlier types.

2. Not only does the T-106 provide the largest exit pupil, 7.32 mm, of any telescopic sight tested, but the quality of vision when using the outer portions of this exit pupil is still good in contrast with T-92 and T-92 for which there was complete loss of definition when the eye was decentered.

3. As a result, however, of the improved definition for all parts of the exit pupil, any parallax present becomes readily noticeable. This parallax becomes appreciable for directions in the field approximately sixty (60) mils off axis. This presents the chief limitation on the reticle area which can be used satisfactorily. In future designs, this point should be given special attention as it is believed that the remedy would not prove too difficult. Perhaps even in the present design a curved reticle could be substituted which would make it possible to more completely use the greater field of good definition provided by this telescope.

4. No similar limitation due to parallax is encountered in the other designs when the reticle is properly placed with respect to the image surface. The chief reason for this is, of course, that the field of good definition provided for by these other telescopes is so limited that parallax has not yet developed as a result of field curvature. The spherical aberration of both the T-92 and T-93 is so great that the image deterioration during eye movement masks any true observation of parallax.

5. The surface coating (bloom) is so successful on telescopes T-106 and M-71-F that despite the employment of far greater number of air-glass surfaces a high transmission is attained and the scattering or contrast loss is not excessive. A more complete study of apparent contrast in various fire control units will be made the subject of a separate report.



TABLE  
GENERAL PROPERTIES OF THE SPECIFIC DESIGN

	P & E	M-70	T-93	T-106	T-92	M-71-F
Magnification	2.77x	3.0x	3.0x	3.1x	5.0x	5.0x
Apparent Field	55°	37°	66°	66°	64°	62°
True field	20°	12.3°	22.7°	22.0°	13.4°	12.8°
Exit pupil on axis, mm	6.22	5.5	6.7	7.3	6.7	7.0
Exit pupil - off axis reduction	slight	severe	moderate	slight	moderate	slight
Contrast (coated)	good	fair	poor	fair	poor	good
Field of good definition, radius in mils	72	55	21	149	14	22
Definition with pupil enlarged or decentered	very good	good	poor	very good	poor	fair
Transmission % (Coated)	52	65	54	69	54	64



## APPENDIX III

### EMPLOYMENT OF SIGHTS

1. In order to provide the basis for selection of sights for different types of employment, Figure 3 has been prepared. This Figure shows by histogram the extent of the true field for different grades of resolving power, together with the reticle requirement and the needs as to total field. The solid block indicates the number of mils off axis over which standard definition or resolution 60 seconds<sup>power</sup> is extended. The central vision of at least thirty (30) per cent of our gunners is of this acuity or better when aided by magnification.
2. The double hatched area extends to the limit of a resolving power of ninety (90) seconds divided by the power of the telescope. The vision of eighty-five (85) per cent of the gunners is equal to or better than this when aided by the magnification of the telescope.
3. The single hatched area is ninety (90) seconds or about equivalent to mediocre unaided vision. Farther out in the field than this point, the vision through the telescope is less good than ordinary vision; but is useful for awareness of flash or motion. It does not appear lacking in sharpness so long as the attention is not directed toward the outer portions of the field.
4. Since the most exacting vision must be used for the greatest ranges, the reticle to be employed should not extend beyond the limits of the solid blocks. Since the extent of the reticle markings depends upon the velocity of the gun, the field of the good definition must be largest for a Howitzer and least for the highest velocity weapon; thus the M-71-F provides for 4100 yards when using the 90 mm gun, whereas it would only provide for 2400 yards with the 75 mm gun or only 1700 yards for the 105 Howitzer. In all this, it is assumed that the bore sight mark will be placed twenty (20) mils above the center of the field. Below the block diagram, the extent of different reticles is indicated for such a bore sight mark placement.
5. In addition to the reticle requirements scale, the rough limits for fair, good and excellent total field are indicated. This appraisal of the desirability of true total field is, of course, an arbitrary judgment. Experience, however, has shown that less than 8° of true field (4° radius) proves highly unsatisfactory in the theater of operations. Cert in considerations should be borne in mind in using this diagram:
  - a. The greater the power, the smaller the corresponding true field for the same apparent field; thus if a telescope of similar excellence to the T-106 were six (6) instead of three (3) power, the field of good definition would drop to seventy-four (74) instead of 149 mils. Similarly, the total field would drop from 22° to 11° radius. Hence high powered sights cannot be expected to have more than a fair or good instead of an excellent true field.



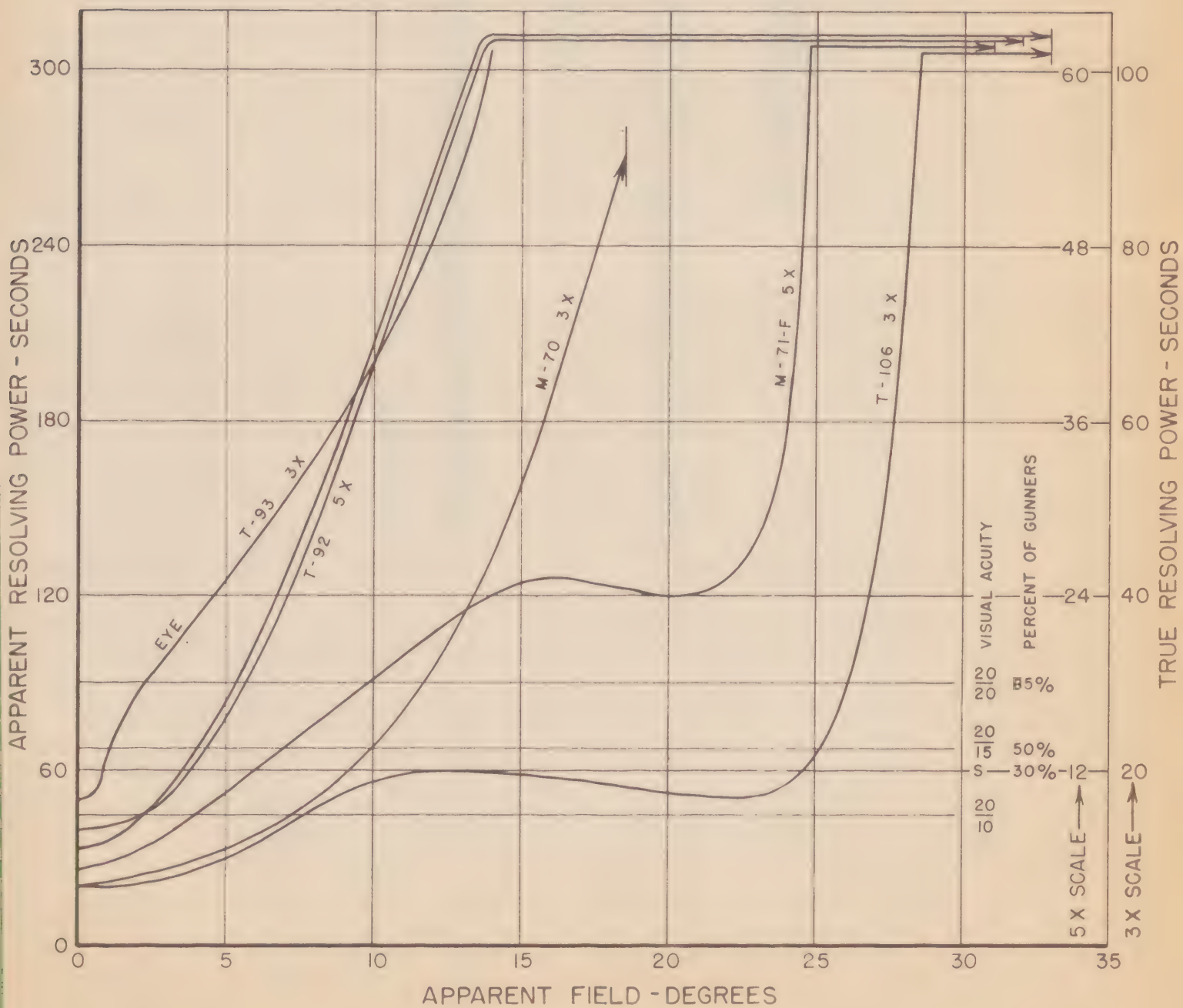
This is a price one pays for greater power. With the greater power, however, the true resolving power is higher; thus for the M-4 the resolving power represented by the solid blocks  $\left(\frac{60 \text{ second}}{\text{power}}\right)$  is  $41\frac{1}{2}$  seconds, whereas for the M-71-F, the solid block represents twelve (12) seconds resolving power. In other words, the gunner will be able to see over three times the minuteness of detail or less than one-third of the size of object. There is a further gain with power for vision at low light intensities. Because of greater enlargement, objects can be seen with lower light intensities provided the contrast is the same.

6. In choosing a sight for use with a specific weapon, the first requirement is that the solid block of the histogram extends out as far as the reticle requires. The second requirement is that the magnification be as great as possible when used for still fire. The third is that the total field be at least fair or as much larger as design permits.



FIG. 1

# COMPARISON OF RESOLVING POWER FIELDS AT THE EYE



Incl. #5



# COMPARISON OF THE APPEARANCE OF SIGHT FIELDS

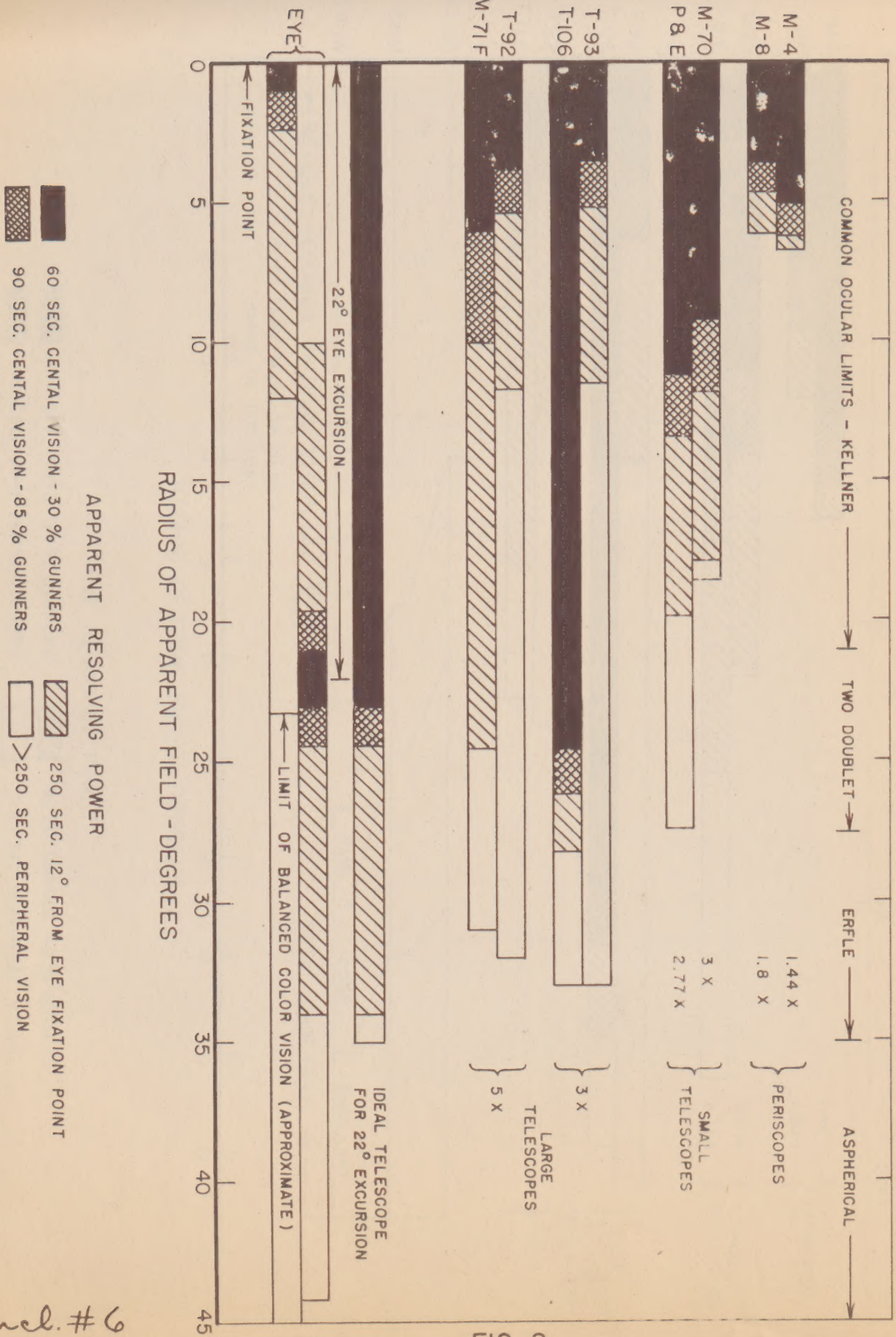


FIG. 2

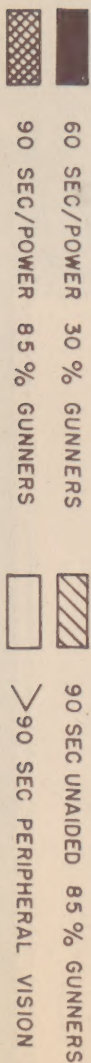
FIG. 2

Incl. #6



# COMPARISON OF SIGHTS BY QUALITY OF TRUE FIELD

## TRUE RESOLVING POWER



RADIUS OF TRUE FIELD - DEGREES

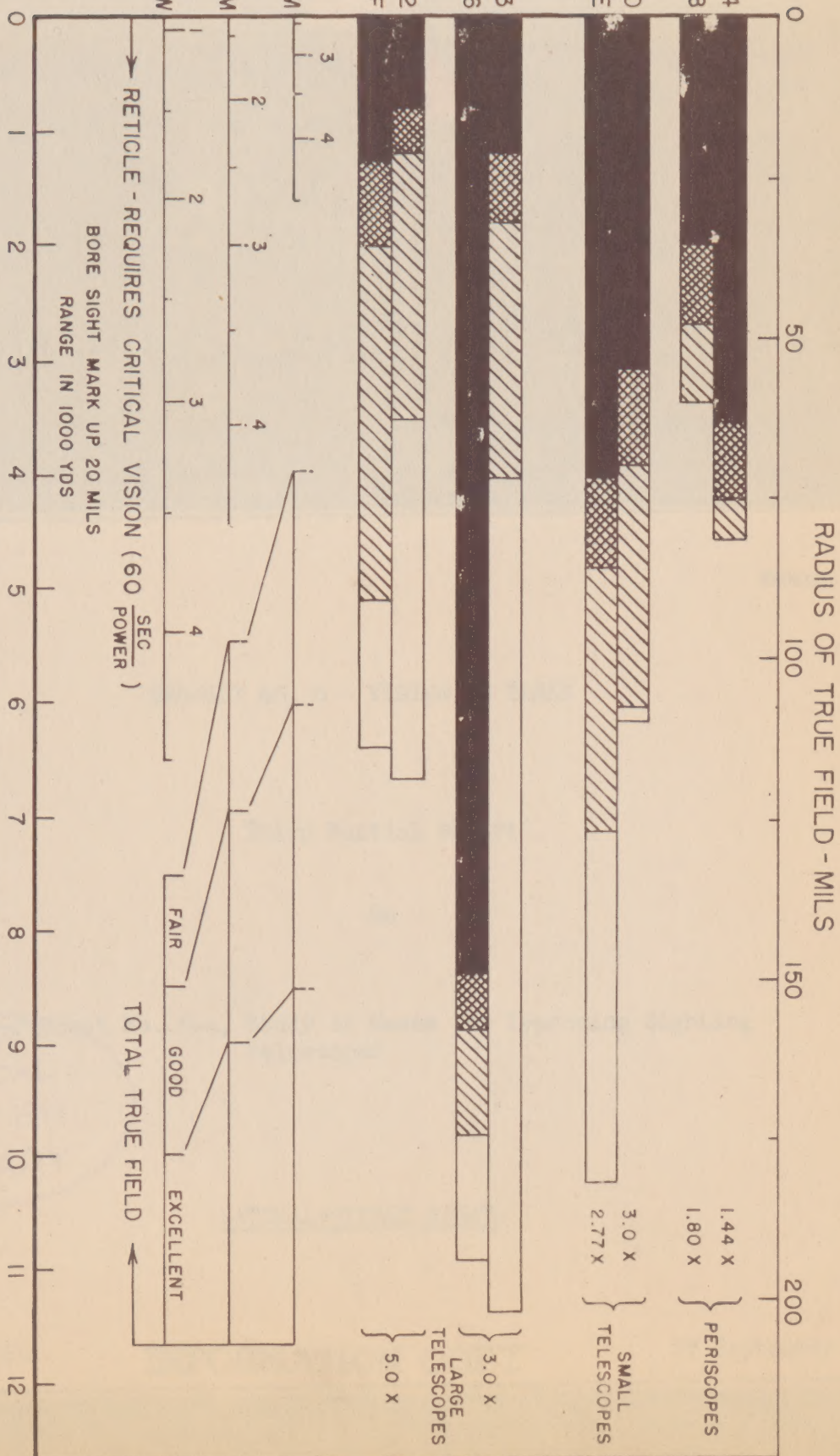


FIG. 3

